SHUTTLE APPLICATION FOR ROTARY RECORDERS

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Introduction

The ATMOS Experiment

The Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment was designed to obtain detailed measurements of the earth's stratospheric chemical composition while mounted in the cargo bay of the Space Shuttle. These measurements are made using infrared absorption . spectroscopy by observing the sun during orbital sunrise and sunset. Observations can be made twice per orbit. This method provides vertical concentration profiles of atmospheric molecular composition from altitudes of 150 km down to 2 km with a minimum height resolution of 2 km. Volume mixing ratios, i.e. molecular concentration ratios, can be determined to levels of 10]2 (parts per trillion) on a global scale. ATMOS can detect and measure the concentrations of most CFC families and their daughter products— molecular species involved with the stratospheric ozone destruction process, oxides of nitrogen, and a wide assortment of atmospheric greenhouse gases. In all, the ATMOS experiment has measured 39 distinct atmospheric molecular species. As a forerunner to advanced earth monitoring instruments, ATMOS has provided the proof-of-principal for infrared atmospheric spectral measurement techniques that will help to optimize the design of future remote sensing instruments.

'l'he mission goal of the ATMOS experiment is to monitor and to detect trends in atmospheric composition due to both solar, natural, and man-made activities through a complete 11 year solar cycle. Missions are to be conducted at 12-18 month intervals. To date, the ATMOS Instrument has flown on two space shuttle missions-- Spacelab 3, in April 1985, and on the ATLAS 1 mission, in March 1992, It is now scheduled to make its third flight on the ATLAS 2 mission, in March of 1993. ATMOS is one of the core experiments on NASA's Atmospheric Laboratory for Applications and Science (ATLAS).

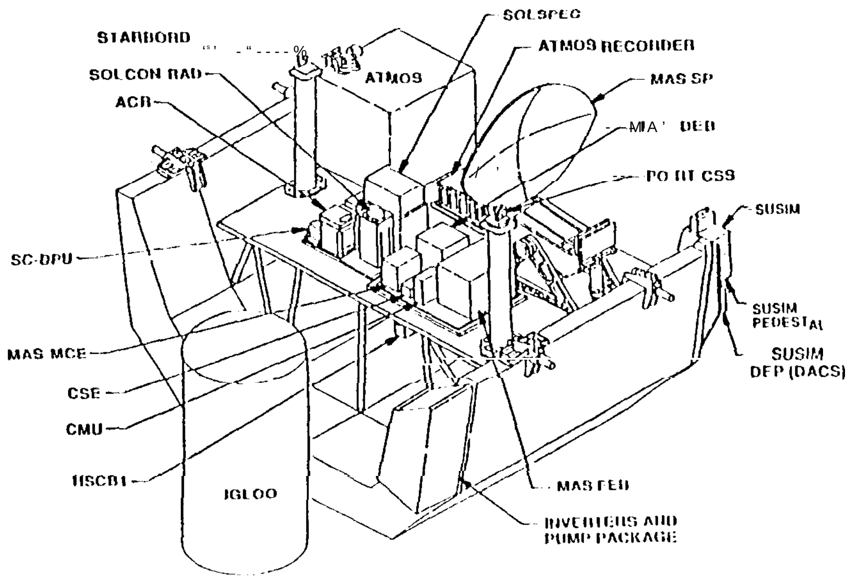

Figure 1. ATLAS 2 Payload

The ATLAS 2 mission will also be the first flight of the ATMOS Recorder Subsystem (ARS), containing the Loral/Schlumberger DV-641O rotary head digital recorder, Figure 1. 'l'his will be primarily an engineering valid ation/demonstration flight for the recorder. Because the ARS will provide a supporting role in the overall ATMOS experiment, it is designated as a subsystem. The ARS will carry only a single D1 -M data cassette, and it will be operated only in the WRITE mode. No in-flight data playbacks are planned.

JPL's Role

The ATMOS experiment is sponsored and funded through NASA's Office of Space Science & Applications (OSSA). Since its start in 1977, JPL has been the NASA center responsible for designing, building, and operating the ATMOS experiment on board the space shuttle. This task is managed through the ATMOS Project Office, which also provides continuing engineering and mission support. The ATMOS Principle Investigator (PI) has the responsibility for defining and planning all ATMOS mission science objectives. The ATMOS science team is also responsible for the development of analysis software, the processing of mission data, and initial dissemination of key data products to the atmospheric science community.

ATMOS Instrument Description

The ATMOS Instrument is an infrared Fourier Transform Spectrometer. Its basic design is that of a modified Michelson interferometer. The instrument covers an infrared spectral band from 2—1 6.5μm (5,000 — 600 cm^{-1}) with a spectral resolution of 0.01 cm^{-1}. It employs two moving optical elements-- cat's eyes, to produce interference fringes over a specified optical path. The optical system uses an internal HeNe laser as a source of reference fringes and for scan velocity control, Other physical characteristics include:

- Single HgCdTe detector
- Active detector cooling to 75 Kelvin using a split-cycle Sterling mechanical cooler
- Selectable optical bandpass filters (8) and fields-of-view (4)
- Active two-axis optical suntracker
- Size: 108.0 cm L x 88.9 cm W x 109.511 (42.5 in x 35.0 in x 43.1 in)
- Total Mass: 250 kg (550 lbs.)
- Maximum Power: 225 Watts DC, 135 Watts AC
- Data Rates: 15.76 Mbps (science data) and 1.28 Kbps (continuous engineering data)

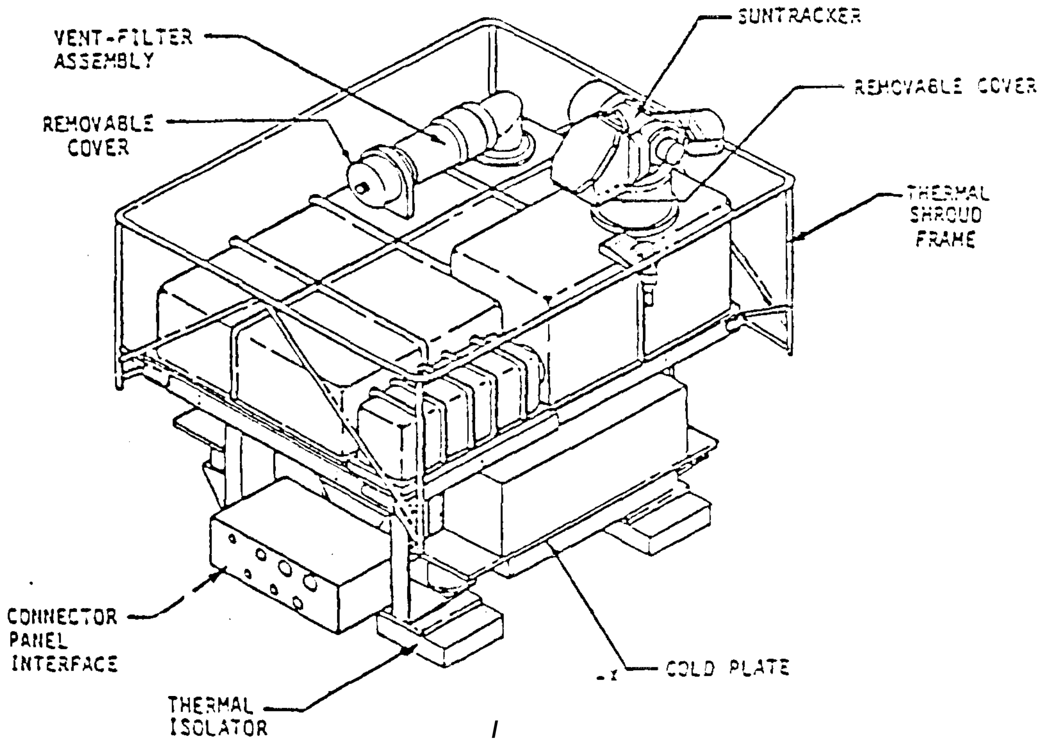

Figure 2. The ATMOS Instrument

Data Recording Requirements

Data Recorders on the Space Shuttle

The fleet of U.S. Space Shuttles have been using various types of instrumentation data recorders from very first flight in 1981. These recorders have been located in the orbiter's crew compartment and in the shuttle's payload bay— in separate pressurized containers and/or in a Spacelab module. While most of these have been linear head recorders, several types of rotary head recorders have also been in use, These include adaptations of commercial VCRs and hand-held video camcorders. None of these rotary head recorders were specifically designed to record high rate digital data. And none of these has had both the data rate and capacity to support many of the scientific instruments typical of many Spacelab/shuttle missions. At best, these recorders can only serve low data rate instruments or act as temporary data buffers. 'I'he following is a description of the rationale behind the adaptation of a new type of high speed digital rotary head recorder for use on the ATMOS shuttle missions.

The Spacelab/Shuttle Data Telemetry System

The success of the ATMOS experiment is critically dependent upon the shuttle's the high rate data downlink system. Ideally, all experiment data is telemetered live to the user on the ground. Usually, this requires the use of the NASA Telemetry Data Relay Satellite System (TDRSS). However, this data path is rather convoluted. Figure 1 depicts the normal telemetry path for the ATMOS experiment data from beginning to end.

ATMOS Instrument data streams are first received through the Spacelab High Rate Multiplexer (HRM). The HRM combines data streams from several other Spacelab experiments, Spacelab subsystems, and Orbiter subsystems into a single HRM composite data format. It also adds a moderate amount of error encoding data, 'l'he HRM can be programmed for data formats ranging from 2 — 48 Mbps. 'l'his composite HRM data stream is then routed to the Orbiter's Ku-band signal processor for transmission to one of the active TDRSS satellites via the Orbiter's steerable Ku-band antenna. The TDRSS, in turn, relays the data stream to the TDRSS receiving ground station at White Sands, New Mexico. From there, the data is directed to one, or more, domestic communications satellites. These satellites rebroadcast the composite data stream to several NASA centers, including the Marshall Space Flight Center (MSFC), in Huntsville, AL and the Goddard Space Flight Center (GSFC) in Greenbelt, MD, where the data is finally captured on NASA facility recorders. The composite stream is played back through a High Rate Demultiplexer (HRDM) in the Payload Operation Control Center (POCC) and each experimenter receives his own data. The ATMOS Project team normally records all of its own data on a 28-track Loral Model 9 linear recorder located in the POCC at MSFC.

When a TDRSS satellite is not within the Ku-band antenna's line of sight, the entire composite HRM data stream must be temporarily stored on board the shuttle until it can be dumped on the next TDRSS acquisition of signal (AOS). During these periods of loss of signal (1,0 S), all HRM composite data is recorded on the Spacelab High Data Rate Recorder (HDRR). 'l'his is an early vintage linear recorder, manufactured by Odetics, located in a pressurized housing in the cargo bay. The HDRR has a very limited capacity-— 20 minutes at the ATMOS data rate. Therefore, it must be dumped- played back to the ground-– at every TDRSS AOS opportunity. It does not have any error correction coding and it has had a somewhat checkered history during Spacelab flights. Other Spacelab data system constraints impact both the number of ATMOS observations and the quality of the science data. On the recent ATLAS 1 mission, the operational requirements of other experiments often dictated the Orbiter's attitude. This directly affected TDRSS acquisitions and often resulted in a reduction in the number of ATMOS real-time downlinks. Problems with HRM format changes, TDRSS bandwidth downlink restrictions, and command links to the HDRR led to loss of about 10 percent of the planned ATMOS observations. Thus, the Spacelab data system has a string of potential serial failure modes.

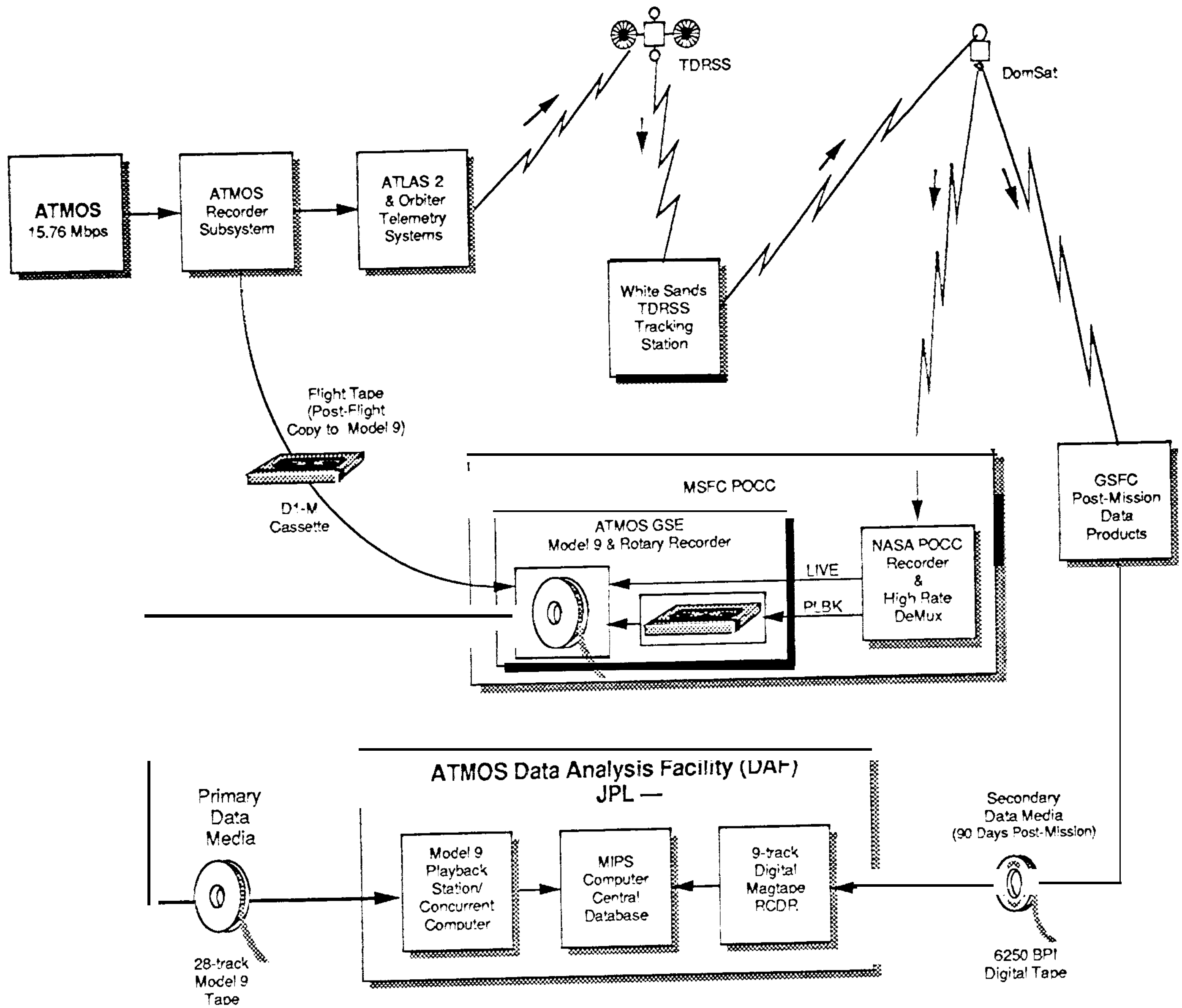

Figure 3. ATMOS Experiment Data Path

ATMOS Requirements for On-board Data Capture

Following the first flight of the ATMOS Instrument, it was recognized that many of these constraints could be eased or eliminated if the ATMOS experiment had its own dedicated on-board data recorder to augment the existing Spacelab data telemetry system. Such a recorder would decrease the data flow resource conflicts between ATMOS and other experiments, provide better operational flexibility, and increase the number of opportunities for observations. It would also reduce the risk of lost science data resulting from a failure of the Spacelab HRM, the HDRR, or the TDRSS system. It would also capture the ATMOS science data at its highest quality. As a secondary data capture device, it would not be mission critical. Therefore, a set of minimum recorder requirements were established as follows:

- High data rate recording capability (1 5.76 MBPS)
- Largest capacity available on a single medium
  - simple, reliable, and widely available recording media
- Error correction encoding/decoding
- Compact and built for a harsh environment
  - minimum modifications to meet STS safety requirements
- Off-the-shelf equipment, if possible
  - simple operation and reliable recording technique
  - standardized on military/industry specifications
- Affordable within the existing ATMOS Project budget funding
  - no NASA funding available for unique hardware development

In 1988, development of a rotary head digital recorder technology, based on the Mil-Std-2179 recording standard, was just emerging. It was seen as the best technology to pursue and the one closest to meeting all of the basic ATMOS requirements. After surveying the small field of instrumentation recorder vendors, JPL found that the Data Acquisition and Recorders (DAR) Division of Schlumberger Industries and Loral Data Systems, formerly Fairchild Weston Systems, Inc., were in the early stages of developing such a recorder for the military aircraft market. JPL selected the Loral/Schlumberger DV-641 O rotary head digital recorder for the ATMOS experiment.

Recorders for NASA's Shuttle Radar Laboratory

At the same time, NASA's Johnson Space Center (JSC) had been looking for a recorder with a similar set of functional requirements. They needed a high speed, high density recorder to support the JPL's SIR-C and Germany's X-SAR radar imaging instruments on the Shuttle Radar Laboratory (SRL) mission, in 1994. The recorders needed to be located in the Orbiter's Aft Flight Deck (AFD) console racks. Because the SRL instruments would be generating huge volumes of data, the shuttle crew members had to have a quick and easy method of changing tapes during the flight. JSC recognized that a ruggedized, cassette-based Mil-Std-21 79 rotary recorder would fulfill their requirements for the SRL mission.

JSC and JPL determined that three of the DV-461 O recorders would satisfy the requirements for the SRL Mission. One recorder would be used to capture the SIR-C'S C-band and L-band radar data at 180 Mbps. The X-SAR's 45 Mbps X-band radar data would be fed to one of the other recorders. The third recorder could be used as an alternate or backup. It was also JSC's plan to put these recorders into the standard orbiter recorder inventory following the SRL flight(s).

System Design Requirements

Spacelab Requirements Heritage

The shuttle payload bay environment and Spacelab interfaces dictated the basic system design requirements. From its inception, the ATMOS Instrument was designed to fly as part of a complement of Spacelab experiments and was not designed to have any direct connections to the space shuttle's (orbiter) systems. NASA requirements dictated that all power, thermal, electrical, command, and data interfaces be compatible with current, circa 1980, Spacelab interface specifications. Likewise, the ATMOS Recorder Subsystem (ARS) had to be designed to maintain this compatibility within the Spacelab payload environment without affecting the design or function of the as-built ATMOS instrument or Spacelab interfaces. It had to be mounted alongside the ATMOS Instrument, on the Spacelab pallet/orthogrid structure in the orbiter payload bay. And it had to function using the available Spacelab resources, Figure 4. Because of this remote location, only one cassette tape can be flown per mission. Therefore, the following system design considerations were made.

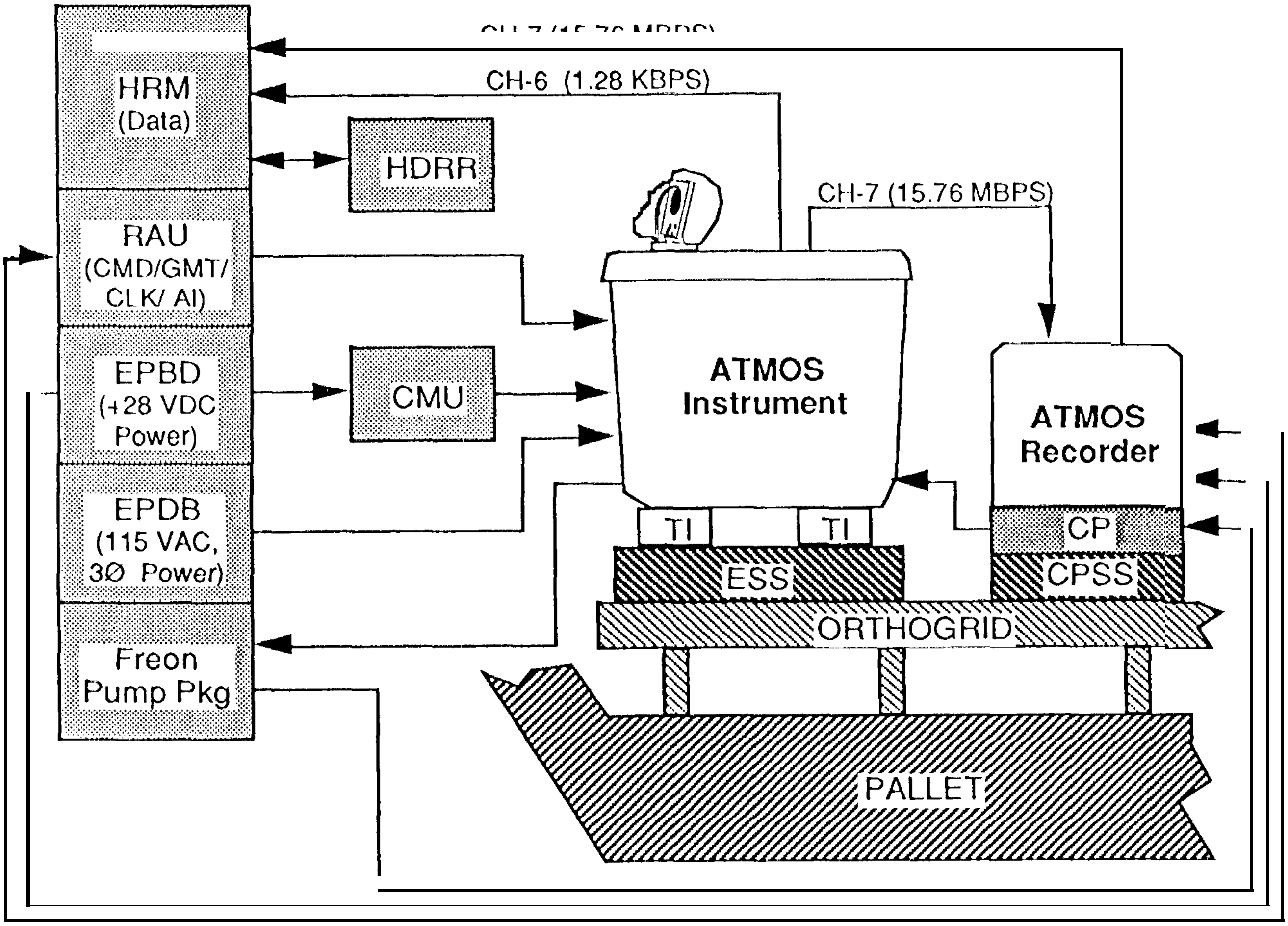

Figure 4. Schematic of Spacelab Interfaces with the ATMOS Instrument and Recorder

Operating Environment:

The ATMOS Recorder Subsystem must survive the launch and landing dynamic environments of a shuttle payload. Once on orbit, it must be able to operate in mircogravity. Because the recorder cannot be operated in a vacuum, the recorder, its power supply, and support electronics must be mounted inside a sealed housing. The contained atmosphere must be tape meclia-compatible.

Physical Mounting:

The entire ARS must be structurally mounted to the payload platform using a coldplate support structure (CPSS)— a NASA-provided structure which has a standard hole pattern covering a fixed area. A freon coldplate is sandwiched between the CPSS and the bottom of the ARS.

Electrical Power:

The Spacelab provides both +28 VDC power and 115 VAC, 3Ø, 400 Hz power through remotely controlled circuit breakers. As the ARS requires only +28 VDC power, it must obtain this power from a 20 ampere service provided by the Electical Power Branch Distributor (EPBD).

Heat Rejection:

All heat generated by the recorder, recorder power supply, and support electronics must be eliminated by conduction. This must be done through a standard NASA coldplate to the active Spacelab freon cooling loop. The coldplate is capable of absorbing a maximum of 1,000 watts of heat. The temperature of the coldplate is determined by the number of instruments and/or subsystems in linked in series, freon flow rate, orbiter attitude, etc. Its maximum temperature range is between +0°C and +40 °C, but normally operates between +5°C and +25°C. A multilayer insulation (MLI) blanket completely covers the ARS housing to minimize radiative heat loss to space and heat, gain from direct solar exposure.

Commanding:

The Spacelab provides control command functions through several avenues. The ATMOS Instrument and the ATMOS Recorder Subsystem are normally controlled by a master timeline (MTL) command sequence, which resides in the Spacelab Experiment Computer (EC). This MTL contains a time-tagged (GMT) list of individual commands and subordinate timelines (STL). STLS contain the list of actual Instrument and ARS command words. The MTL is updated on a regular basis. When the MTL calls an STL at the prescribed GMT, the STL'S command list is executed. Each command is separated by a predetermined time delay. In its current configuration, the ARS has a vocabulary of only five simple commands. Alternately, these commands can be issue directly from the shuttle crew's Data Display Unit or from an investigator's terminal on the ground. This method of commanding will only be used in contingency situations.

Control Interface:

Commands issued by the EC are routed to a Spacelab unique signal interface called the Remote Acquisition Unit (RAU). This device is capable of sending and receiving information to/from the payloads in serial, discrete (pulsed or level), and analog forms. At this time, the ARS only uses discrete levels for control commands. The ARS outputs two analog telemetry signals and three discrete level status signals back to the MU. These signal are telemetered to the ground in the experiment computer's input/output (ECIO) data stream.

Data Interfaces:

The ARS was designed to be inserted between the ATMOS Instrument's high rate data channel and the Spacelab's HRM data input interface. Since the ATMOS Recorder Subsystem was initially intended to act as a secondary data capture device, it was necessary to design the data interface in such a way that it would not interrupt or contaminate the data path. The live ATMOS 15.76 Mbps data and clock streams are simultaneously fed to the recorder and to the Spacelab HRM interface. If the recorder completely fails during flight, these ATMOS data streams will still be routed to the primary Spacelab/shuttle data telemetry systems with no loss of planned science data. The recorder will be used only in the **WRITE** mode and no playbacks are planned. Therefore, there are no requirements to generate another HRM signal,

Interface Compatibility Verification and Flight Safety Requirements:
For all Spacelab instruments and support equipment, there is a set of design and operational requirements which must be met and verified. These requirements are defined by the mission environment and shuttle/crew safety concerns. Depending on the requirement, verification is accomplished by analysis, test, inspection, or a combination of these.

Description of the ATMOS Recorder Subsystem

The design of the ARS interfaces were kept as simple as possible. Although this simplicity would restrict our operational flexibility, it would reduce risk associated with a new piece of hardware. Lack of adequate schedule time and funds also delayed the development of sophisticated control and telemetry interfaces.

The components of the ATMOS Recorder Subsystem are shown in Figure 3. It consists of four primary assemblies as follows:

- Pressurized Housing Assembly: contains all other components at -112 atmosphere
- Recorder: Loral/Schlumberger DV 6410 compact rotary head digital recorder
- Power Supply: Loral/Schlumberger model DA 4010 (+28 VDC)
- Electronics Interface Unit provides all electrical, command, and data interfaces

Other physical characteristics of the ARS are as follows:

- Size: 76,5 cm L x 44.5 cm W x 51.3 H (30.1 in x 17.5 in x 20.2 in)
- Total Mass: 117 kg (257 lbs.)
- Power: Standby 75 W; Recording 260 W_{ave}; 365 W_{peak}
- Maximum recording capacity: 6.3 hours at ATMOS data rate (80 -85 observations)

Pressurized Housing Assembly

Teledyne Brown Engineering (TBE), Huntsville, Alabama, was contracted by the ATMOS Project to perform a design verification assessment and analysis on the recorder's mechanical design. They made recommendations for structural modifications and material substitutions, only where necessary, to meet the STS safety requirements. TBE was also contracted to design and build a pressurized housing for the recorder, its power supply, and the support electronics.

The pressurized housing was made in three sections. Each section is hermetically sealed together with Parker Gasko-Seals. A tape access door is provided on one end of the upper housing assembly. This, too, is sealed with a Gasko-Seal. TBE determined that the DV-641 O could be operated effectively at 1/2 of an atmosphere (-7.4 psia) in the ATMOS mission duty cycle. 'I'his design philosophy prevented the housing from falling under NASA's rigid definition of a pressurized vessel. It still provided an adequate amount of *air mass* for system cooling and for the tape/head interface aerodynamics. To eliminate NASA's fire safety concerns, the housing was to be evacuated and backfilled (pressurized) with GN_2, containing a controlled amount of water vapor for the tape media.

Heat was to be removed from all internal boxes through forced convention, Internal air circulation was provided by the recorder's fans, the recorder power supply's fans, and the pressurized housing's two high flow fans. The flow of air was directed across a series of thin fins which were milled into the bottom portion of the housing. Heat picked up by these fins is then conducted out of the bottom of the housing into the NASA freon coldplate. This system has a large thermal margin.

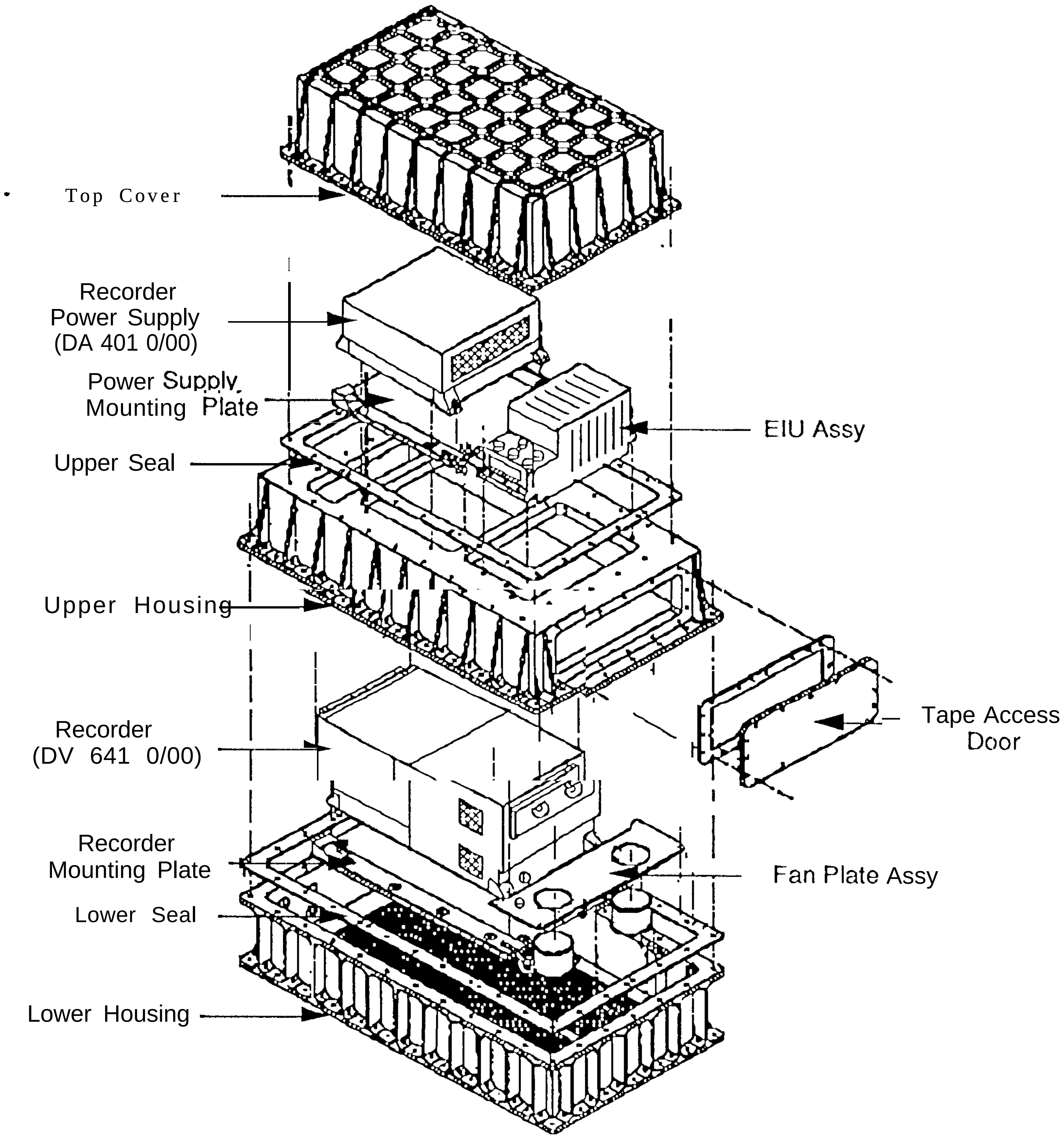

Figure 5. Components of the ATMOS Recorder Subsystem

Rotary Recorder

The ARS recorder is a Loral/Schlumberger model DV 6410 compact digital rotary head recorder Serial No. 001. This unit was originally a preproduction model built by the R&D staff at Schlumberger Industries in Vélizy, France. Because of NASA's tight integration and test schedule, it was necessary to use this unit instead of a fully qualified production unit. It was upgraded to near production revision level and subjected to a series of environment stress screening tests and an acceptance test at the manufacturer. 'l'he recorder is mounted on the vendor-supplied mounting frame which is fastened to the bottom of the pressurized housing. It has its own set of four cooling fans on it rear panel.

Recorder Power Supply

The DA 4010 +28 VDC power supply is also mounted on vendor-supplied mounting frame. This frame is attached the the upper level of the main pressurized housing. The power supply contains its own set of two cooling fans.

Electronics Interface Unit

The Electronics Interface Unit (EIU) is a card cage chassis assembly which is mounted on the upper level of the main pressurized housing in front of the recorder power supply, It relies on the housing's forced air circulation for cooling. The EIU contains five (5) printed wiring board assemblies. The chassis has room for three more. A functional diagram of the EIU interfaces is shown in Figure 4. 'l'he EIU electronic assemblies perform the following duties:

RCCB Controller:

Primary circuit protection and power switching is controlled by two Remote Controlled Circuit Breakers (RCCBs) inside the pressurized housing. The incoming primary +28 vdc Spacelab power is divided into two legs. One leg is directed to the recorder through a 15 amp RCCB, while a 5 amp RCCB controls the power to the EIU and the two large fans. Each RCCB is activated by a separate Discrete Output (DO) command from the RAU to the Controller. In turn, each RCCB has is own Discrete Input (DI) power status indicator signal which is sent back to the RAU.

EIU Power Supply:

Several electronic subassemblies in the EIU require secondary dc power. This is provided by the EIU Power Supply. 'l'he EIU power supply receives primary +28 vdc power via the 5 amp RCCB . Its modular de-to-de converter provides four secondary voltages, ±15 vdc and ±5 vdc to the other EIU electronics assemblies,

Recorder Controller:

The DV-641O rotary head digital recorder is commanded by the EIU Recorder Controller, The Recorder Controller is the command interface between the RAU and the recorder. Upon receipt of a single DO command (RECORDER ON) from the RAU, the Recorder Controller starts a timed sequence of commands to the recorder. It commands the DV-641O through the RS-422 communications interface. Only two commands are required to begin the recording of ATMOS data; POWER ON and **WRITE.** These command words are stored in an EPROM on the PWB assembly. The time delay from receipt of the RAU's RECORDER ON command to the actual recording of data has been timed at 45 seconds. This delay is taken into account in the MTL.

As the recorder begins writing data to tape, the Controller relays the DV-641O's AT SPEED status indicator to the RAU via a DI signal level. Recording is stopped when the RAU drops the DO signal (RECORDER OFF). The Recorder Controller issues a STOP command to the recorder. After a programmed delay of approximately 1 minute, the recorder automatically goes into its STANDBY mode until the next scheduled operation. If the Recorder Controller does not receive the RAU signal transition after a period of approximately 5.5 minutes, it will automatically issue the STOP command to the recorder. This Recorder Controller fail-safe feature will prevent the accidental waste of tape.

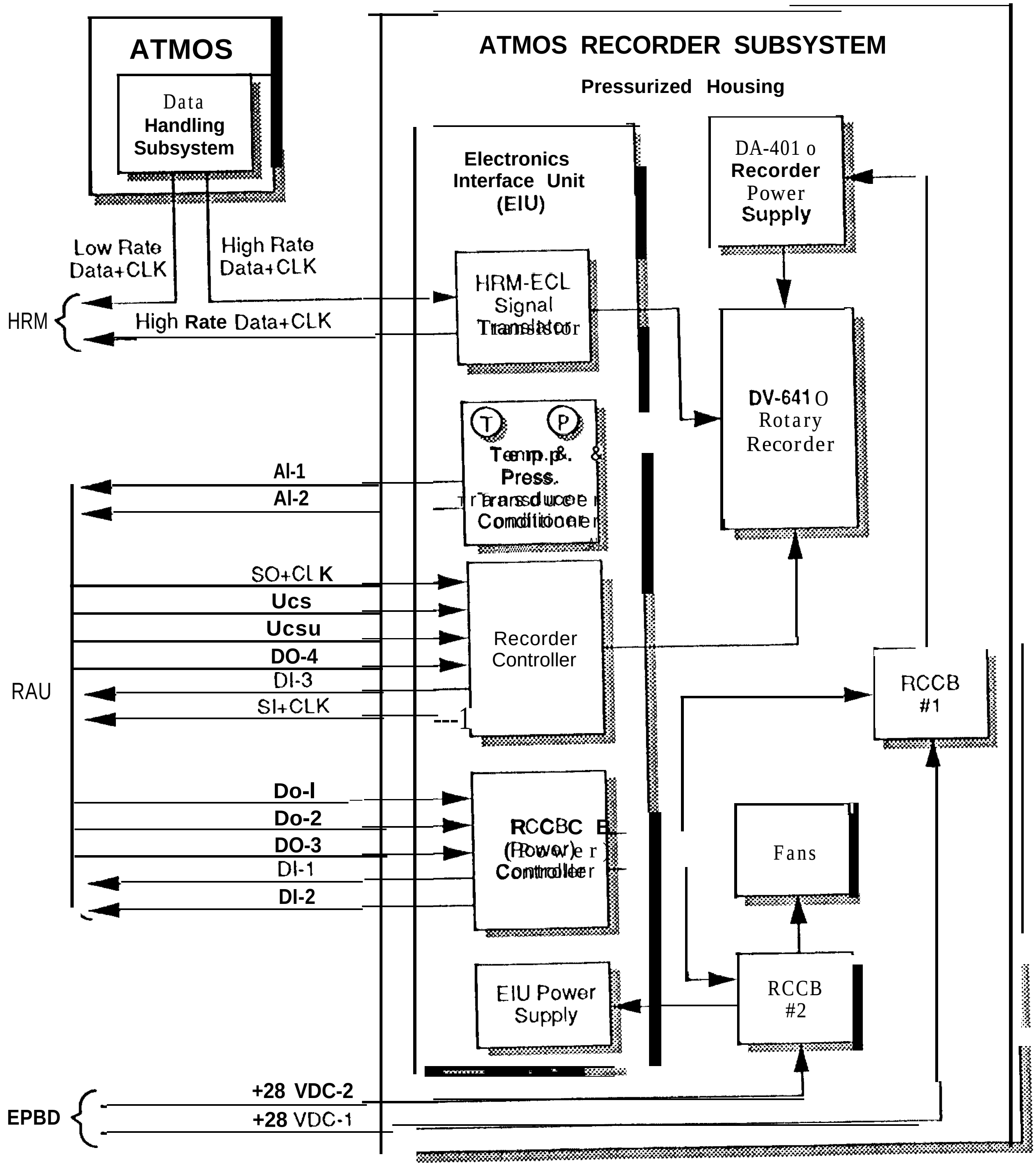

Figure 6. ATMOS Recorder Subsystem EIU Functional Diagram

Preparations for the ATLAS 2 Mission

Recorder Subsystem Component Integration

Five months before to the final delivery of the DV-6410 recorder to JPL, Schlumberger loaned the preproduction recorder unit to the Project for fit, function, and interface checkouts, The fit-check allowed the ATMOS Project to custom fit the cable harness inside the cramped space of the pressurized housing assembly. Extensive command software interface tests were conducted by both ATMOS and SIR-C. When the upgraded recorder unit was delivered in late July 1992, the entire ARS was integrated and tested at JPL in just six weeks, A brief, but very important data interface test was conducted with the ATMOS Instrument just prior to its delivery to the Kennedy Space Center.

Flight Qualification Testing

The fully integrated ARS was put through an abbreviated series of flight acceptance tests. These included random vibration, EMC, and thermal characterization tests. The ARS must only survive the shuttle launch and landing dynamic environment while in a non-powered state.

Sine Sweep and Random Vibration Tests:

A set of random vibration tests were performed at JPL using an electrodynamics shaker. Preceding each random vibration test axis, a low level (0.5 g) sine sweep was performed in each axis to determine the fundamental frequencies for the integrated subsystem. The frequency sweep range was from 5 to 2,000 Hz. Six triaxial and one single axis transducers were used measure the ARS dynamics responses. A baseline functional test was performed before testing and repeated between each test axis. Test levels were dictated by MSFC's specifications for the type of payload mounting, by the total mass of the ARS, and the payload's coupled loads model. The ARS was unpowered during each test and each run was 1 minute per axis. The random vibration test levels are shown in Table 1. It was determined that the lowest fundamental frequencies were well above the minimum allowed for this type of Spacelab payload. No recorder functional problems were encountered during the random vibration tests.

Test Axis	20-82 (Hz)	85-150 (Hz)	150-350 (Hz)	350-2,000 (Hz)	RMS Levels (g_{rms})
X- & Y-Axes	0.006 g^2/Hz	+6 dB/oct.	0.02 g^2/Hz	-i' dB/oct.	3.2
Z-Axis	0.006 g^2/Hz	+9 dB/oct.	0.06 g^2/Hz	-9 dB/oct.	4.8

Table 1. Flight Acceptance Random Vibration Test Levels

EMC Tests:

The integrated ARS was placed inside of a screen room for electromagnetic compatibility (EMC) testing. This series of required emissions measurements were based on MSFC-SPEC-521 B, which is equivalent to Mil-Std-461C. included were CE01/CE03 conducted emissions tests, the RE02 Electric-field and RE04 Magnetic-field radiated emissions tests, and a special TT01 transient emissions test. Conducted emissions above specifications were encountered during the tests. The problem was found to be an improper ground in the EIU's secondary power supply. It was corrected and the EMC tests were repeated. Except for a very small emission (4-5 dBμA), the ARS conducted emissions were all well within specifications. However, several narrow band radiated E-field emissions were 15-20 dBμA above the MSFC-SPEC-521B specifications. These were identified as recorder reproduce clock frequencies. NASA granted an exception for these emissions and the ARS will fly as is. The ARS passed the 'TT01 transient test with no problems.

Thermal Characterization Test:

The only remaining area of concern that had not been validated by test was the ARS thermal characteristics. The design margin was known to be adequate for the recorder's mission duty cycle— maximum operating power of 260W for five minutes every 32 to 48 minutes (twice per orbit) and a continuous standby power of 75 W. 'l'he ideal test setup would have involved the use of a coldplate or other heat exchanger in a vacuum chamber to simulate the Spacelab's freon cooling system in space. However, this approach was not within schedule or budget. Since the ATMOS Project was running out of time, a decision was made to delete the thermal/vacuum test on the complete ARS. The pressurized housing had been leak tested by TBE. Any risk associated with losing the ARS' atmosphere could be determined by monitoring leakage trends during the payload integration and testing phases. The question to be answered was how efficient is the heat transfer from the forced convection atmosphere to the pressurized housing structure? A thermal characterization test plan was devised to measure this parameter without using a vacuum chamber and coldplate.

The plan was to isolate the ATMOS Recorder Subsystem from all external avenues of heat loss while measuring its total heat capacity during operation. The ARS was sealed inside of a large foam-filled box to minimize external heat losses due to convection and radiation. Seven temperature transducers were mounted inside the ARS to measure the air temperature at various locations. One transducer was placed on the outside bottom of the pressurized housing to measure the heat transfer. 'l'he housing had been backfilled to 8 psia with moisturized GN_2. The recorder was repeatedly cycled through its mission operational cycle while the temperature transducer outputs and total input current were registered on strip chart recorders. The EIU's temperature and pressure transducers were also monitored and recorded for calibration purposes.

The results of this thermal characterization test showed that operating the ARS caused the internal air temperature to rise by 1.5 to 2.0 °C during each full power operation. The external temperature transducer indicated a corresponding delta temperature rise of 1.3 to 1.5 "C— a heat transfer efficiency of ~70%. If an actual Spacelab coldplate, with a maximum heat capacity of 1,000 W, had been used the ARS would require only 1/3 to 1/2 of its thermal design capacity.

ATLAS 2 Payload Integration and Testing

Level IV Integration and Functional Testing:

The ATMOS Recorder Assembly was sealed containing a moisturized atmosphere of GN_2 at nominal pressure 8.5 ±0.5 psia. 'l'he ARS was delivered to KSC in late September 1992 for the start of Level N integration. It was shipped as a unit in its own container. A successful off-line functional test was performed in the high bay of the Operations and Checkout (O&C) Building using the ARS' ground support. equipment. The ARS was hoisted onto the ATLAS 2 pallet orthogrid next the ATMOS Instrument were it was physically integrated to the Spacelab coldplate support structure (CPSS). Mating of all electrical/electronic connections followed.

A complete Level IV Functional Test was performed utilizing all of the Spacelab resources for the first time. The ATMOS Instrument was also turned on to provide a data stream and clock source. 'l'he ARS was commanded through its operational routine using all applicable command methods. Live ATMOS Instrument data was passed through the ARS to the Spacelab telemetry systems and eventually to a set of ground support equipment (GSE) located in the on-line User Room of the O&C Building. The live data was recorded on a 28-track linear recorder that is part of the GSE that is normally used to capture data from the ATMOS Instrument during ground testing and during the mission. The ATMOS Recorder Subsystem's operational status was continuously monitored through the Spacelab EC1O telemetry stream on a Peripheral Processor terminal located in the User Room. In addition, the recorder's status and command responses were independently monitored at the test stand by Project personnel using a Loral/Schlumberger DA 6620 handheld Remote Control Unit (RCU). All ARS functional operations were completed successfully.

Although no BER test set was available to the Project at the time, a coarse verification of the data content and quality was accomplished by playing back the digital cassette's recorded data through a temporary set of data lines to our GSE's 28-track linear recorder for re-recording. As the ARS controller was not designed to play back data during the mission, the handheld RCU was used to rewind and play back the data segment. The linear tape containing the two sets of data was later taken back to the ATMOS data analysis facility (DAF) for comparison.

Level 111/11 MST:

A second set of tests was performed *in* early December 1992. The ATLAS 2 Level III/II Mission Sequence Test (MST) operated all the experiments, including ATMOS, in slices of the actual mission timeline. The ATMOS Instrument was operated through six observation sequences and the ARS was operational during three of these. Again, the recorder operated as designed. Following this test, the pressurized housing was backfilled to 1 atmosphere and the digital cassette used for testing was removed. It was replaced by a new, degaussed Ill-M cassette tape. A sample portion of data was recorded and played back, It revealed bit error bursts that are characteristic of dirty tape. Because there are currently no cleaner/winder/packer/certifiers available on the open market, none of our tapes had been properly cleaned and certified. A second cassette was installed in place of the first and the recorder/playback was repeated. This time the results were much better.

Level I- SL/STS IVT

One last powered test will be conducted in early February 1993. This will be a Spacelab/Orbiter Interface Verification Test (I VT) during which a health check test will be conducted on several experiments. The ATMOS Instrument and the ATMOS Recorder Subsystem will be operated in an abbreviated functional test. Critical subsystems in both will be assessed for flight readiness. If a problem is found, no corrective actions can be taken. However, mission planning can be changed to work around the problem or minimize the impact of the problem to the success of the mission.

ATLAS 2 Mission Plan

The ATLAS 2 mission is currently scheduled to be launched in late March 1993. The ATMOS Instrument and the ATMOS Recorder Subsystem will be powered on during payload activation; approximately mission elapsed time (MET) of 2h40m. Both will stay a continuous standby state for the duration of the mission, except during planned observations. Because of the finite capacity of the single cassette tape, mission planning guidelines for the use of the ARS is strictly defined. The ARS will be operated only during those ATMOS sunrise/sunset observations that occur during a total or partial TDRSS loss-of-signal. Live downlinks will not require the use of the ATMOS Recorder Subsystem. Recordings will be made until the recorder is full— approximately 80-85 observations out of the planned total of 160. When this occurs, the ARS active operation will be removed from the remaining mission timeline. It will remain in a standby state until the payload is powered down and deactivated before landing. If any part of the ARS fails during the mission, it can be powered off and still not affect the nominal ATMOS Instrument observations.

During the mission, the ATMOS Project Team will be monitoring the ATMOS Instrument and the ARS from the POCC facility at MSFC. The Team will capture all live ATMOS data on the GSE's 28-track Loral Model 9 linear recorder on 14-inch reels of 1 -inch wide tape. Normal POCC data playbacks of dumped HDRR data will be captured by a separate rack-mounted, ground version of the rotary recorder, a DV-6420. This data set should be identical to the one that is simultaneously captured by the ARS flight recorder.

‘l’he ATMOS Project will not have access to the data cassette until after the ARS is reintegrated from the ATLAS 2 payload. This normally occurs within thirty (30) days after landing at KSC. An additional one week’s delay is incurred if the landing is diverted to Edwards AFB. ‘J’he present ATMOS DAF computer system cannot directly read in data at rates above 2 Mbps. Therefore, the digital cassette will bc played back, either from the ARS or from the rack-mounted rotary recorder, onto the 28-track Model 9 linear recorder. These submaster recordings will be made at the full data rate of 15.76 Mbps— at an HUG recording speed of 30 IPS. Finally, the 14-inch reels will be played back into the DAF computer system, at 2 Mbps, for processing and analysis.

Comments and Conclusion

This first flight of the ATMOS Recorder Subsystem is truly an engineering validation/demonstration flight. 'l'he successful operation and performance of the DV-4610 rotary recorder is a highly desirable and achievable goal. 'l'he ATMOS Project has made every effort within its capability to insure success of this first flight. This entire effort has had the full support of NASA Headquarters.

Areas of Concern

There are several areas on concern that were not resolved prior to final integration and testing of the ATMOS Recorder Subsystem. The focus of these concerns is the tape medium itself, At this time, our experience is limited to a single vendor, Sony. Visual inspection of several cassettes, from the same lot, revealed a large variation in amount of visible manufacturing debris. This physical contamination was even more revealing after the cassette had been degaussed. Apparently the induced vibration from the degausser either shook loose unseen debris or it generated additional particles through abrasion of internal cassette parts. This issue is far from being resolved.

Because of the immature nature of the Mil-Std-2179 recorder market, there are, at present, no reliable means of cleaning and certifying tape media in D1 cassettes. The development progress of the known U.S. vendors of cleaner/winder/packer machines has, unfortunately, lagged the needs of our launch schedule. The ATMOS Project, having only one recorder at its disposal and lacking a BER test set, could not certify quality of the tapes that were assigned to be *flight* tapes. This is clearly the biggest risk to the successful recording of the ATMOS science data by the ARS.

Future Upgrades and Modifications

Following the ATLAS 2 flight, the S/N 001 rotary recorder will be removed from the ARS and shipped back to Schlumberger for a complete retrofit to the latest qualification standards. A second, qualified recorder unit will be installed in the AILS. It will be used for further ground testing and it will probably fly on the ATLAS 3 mission. 'l'he first unit will then serve as a spare and for qualifying tapes.

As a near-term goal, the ATMOS Project has been investigating methods of extending the capacity of a single digital cassette tape so that all ATMOS observations can be recorded. An obvious approach will be to use a thinner, 1,3 roil, tape when it becomes available. Another approach is to perform some level of data compression. This will require a fast chip set for on-the-fly data compression and a slower data recording speed (2-head recorder).

Plans are being made to upgrade the EIU's recorder controller to allow some additional two-way communication between the EIU and the recorder. 'l'he goal is obtain a regular series of status reports from the recorder, in addition to the one and only AT SPEED indicator. The status report will provide a readout of the tape's last used TSID, along with other engineering parameters, alarms, and fault indicators. The ARS cabling and the RAU's cabling have already been provided with the necessary signal lines.

Finally, the ATMOS science team has been requesting a better knowledge of the shuttle's true orbital position during ATMOS observations. The present system is not accurate enough for precise determination of line-of-sight altitudes (tangent heights) to better than 2-10 km. This level of precision can only be achieved if NASA can be persuaded to install and utilize GPS receivers on orbiters. If GPS data were available, the ATMOS Project will modify the ARS to record the raw GPS position and time data on the auxiliary track of rotary recorder. 'I'he GPS data would be processed post-mission and correlated to the ATMOS science data.

Conclusions

The ATMOS Recorder Subsystem will be a great benefit to the ATMOS experiment. By maximizing the amount and quality of scientific data returned by ATMOS during an ATLAS mission, the entire Mission to Planet Earth scientific investigation of the earth's atmosphere benefits. A successful demonstration of the ARS will show that off-the-shelf military grade equipment can be flown in a shuttle environment without major modifications or a large development expenditure . This is a savings to NASA and to the U.S. taxpayer.

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Acronyms

AFD	Aft Flight Deck
ARS	ATMOS Recorder Subsystem
ATLAS	Atmospheric Laboratory for Applications and Science
ATMOS	Atmospheric Trace Molecule Spectroscopy
BCE	Bench Checkout Equipment
BFU	Backfill Unit (GN_2)
CPSS	Coldplate Support Structure
DAR	Data Acquisition and Recorders (Schlumberger)
DDS	Data Display System
EC	Experiment Computer
ECL	Emitter Coupled Logic
EC10	Experiment Computer Input/Output
EIU	Electronics Interface Unit
GSE	Ground Support. Equipment
GSFC	Goddard Space Flight Center
GN_2	Gaseous Nitrogen
GPS	Global Positioning System
GSS	Ground Support Subsystem
HgCdTe	Mecury Cadmium Telluride
HDRR	High Data Rate Recorder
HRM	High Rate Multiplexer
IPS	Inches Per Second
IRIG	Inter-Range Instrumentation Group
Iv'l'	Interface Verification Test

JPL	Jet Propulsion Laboratory
Kbps	Kilobits per second
KUSP	Ku-band Signal Processor
LDS	Loral Data Systems
Mbps	Megabits per second
MLI	Multi-Layer Insulation
MSFC	Marshall Space Flight Center
NASA	National Aeronautics & Space Administration
O&C	Operations and Checkout
OSSA	Office of Space Science & Applications
PI	Principle Investigator
PMIC	Payload Mission Integration Contractor
POCC	Payload Operations Control Center
PP	Peripheral Processor
RAU	Remote Acquisition Unit
RCCB	Remote Control Circuit Breaker
RCU	Remote Control Unit (handheld, Recorder)
SIR-C	Shuttle Imaging Radar- "C" Version
SL	Spacelab
SRL	Shuttle Radar Laboratory
STS	Space Transportation Systems (Space Shuttle)
TSID	Track Set identification (Recorder)
X-SAR	X-Band Synthetic Aperture Radar

JPL	Jet Propulsion Laboratory
Kbps	Kilobits per second
KUSP	Ku-band Signal Processor
LDS	Loral Data Systems
Mbps	Megabits per second
ML]	Multi-Layer Insulation
MSFC	Marshall Space Flight Center
NASA	National Aeronautics & Space Administration
O&C	Operations and Checkout
OSSA	Office of Space Science & Applications
PI	Principle Investigator
PMIC	Payload Mission Integration Contractor
POCC	Payload Operations Control Center
PP	Peripheral Processor
RAU	Remote Acquisition Unit
RCCB	Remote Control Circuit Breaker
Rcu	Remote Control Unit (Handheld, Recorder)
SIR-C	Shuttle Imaging Radar- "C" Version
SL	Spacelab
SRI,	Shuttle Radar Laboratory
STS	Space Transportation Systems (Space Shuttle)
TSID	Track Set Identification (Recorder)
X-SAR	X-Band Synthetic Aperture Radar